Environmental Taxation and Mergers in Oligopoly Markets with Product Differentiation

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Abstract

We analyze the effect of mergers on optimal environmental taxation in a Cournot oligopoly market with product differentiation. Our result indicates that the adjustment in emission tax crucially depends on the post-merger output distortion and pollution intensities. Specifically, we find that the optimal emission tax increases post-merger as long as pollution intensity of firms is higher and output distortion smaller post-merger than pre-merger. Furthermore, our result suggests that there is no need to revise environmental policy in markets where pollution intensity of firms does not change post-merger and (i) products are completely differentiated, or (ii) there are many firms for any degree of product differentiation.

JEL Classification: L, Q5, G34

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1 Introduction

The rise in greenhouse gases (GHG) and concern for global warming has pushed many countries to adopt market-based policies to reduce pollution. For example, Ireland enacted a carbon tax in 2010 on most fossil fuels. Chile has recently enacted a pollution tax targeting large factories and the electricity sector; and European countries like Sweden and Finland had pioneered in the carbon/energy tax since the early 1990s. US states and local governments are also taking noteworthy actions to mitigate GHG emissions (Damassa et al., 2012). For instance, nine northeastern states adopted a cap-and-trade program in 2009 to reduce GHG emissions in the electricity sector. Boulder, Colorado has approved the carbon tax since 2006, the first ever in the entire country.[1]

With the conclusion of the 2015 Climate Change Conference in Paris, nations are expected to raise targets of anthropogenic GHG emission reduction. Energy-intensive manufacturing (e.g. cement), the electric power and transportation industries are expected to be the most affected by such policies. Due to their scale economies these industries are constantly seeking to consolidate. For instance, the US utility sector has seen the highest levels of merger and acquisition deals in 2011 (FW December 2012). Thus, nations ought to take into consideration the effect of industry changes due to restructuring on their modification of existing environmental policies.

Another example is pollution-intensive manufacturing such as the production of chemicals, plastic materials, paint and varnish, pesticides and agricultural chemicals which has record number of firms seeking to sell their assets in acquisition deals (Factset USA, 2016; Hettige et al., 1995). In 2015 in the US there were 66 merger and acquisition deals in the chemical production industry, 24 deals for plastic producers, and 22 deals for pesticide and agricultural chemical producers. In industries where mergers and acquisitions are taking place, what is the optimal environmental policy response? The purpose of the study is to

[1]Source: http://www.carbontax.org/where-carbon-is-taxed/

examine the role of output distortion associated with mergers and pollution intensity in the optimal adjustment of emission tax in oligopoly markets.

We set up a model to characterize the optimal emission tax in a Cournot market where firms are producing differentiated products. We then model a merger among two firms and examine how the optimally chosen policy changes (if at all) in the post-merger market. Our result indicates that the adjustment in the emission tax crucially depends on the post-merger output distortion and pollution intensities. Specifically, given our model framework we find that the optimal emission tax increases post-merger as long as output distortion relative to pollution damages is smaller post-merger and pollution intensity of firms post-merger is sufficiently higher compared to pre-merger values. Furthermore our result suggests that there is no need to revise environmental policy (specifically emission tax) post-merger in markets where pollution intensity of firms does not change post-merger and (*i*) products are completely differentiated, or (*ii*) there are many firms for any degree of product differentiation.

The reason for (i) is that complete product differentiation means limited power for merged firm to worsen the output distortion post-merger. In addition, since there is no change in pollution intensity post-merger, there will be no need to adjust the emission tax after the merger takes place. This underlines the importance of changes in pollution intensities and changes in output distortions in prompting an optimal change in the emission tax. The result in (ii) holds because the lack of sufficient output distortion post-merger when there are many firms in the market, removes the need to adjust the optimal taxation.

The contribution of this study is at the intersection of three important branches of the existing literature. First, despite the growing number of studies on mergers and acquisitions, there are not many studies that include pollution parameters and resulting regulation in their models. The merger literature from Salant et al. (1983) to current (e.g. Blonigen and Pierce, 2015) has largely focused on examining the motivations for and the effects of mergers (among pollution neutral firms) on market power and efficiency. There are merger studies that examine optimal change in other types of policies after mergers take place, but none of them examine optimal environmental policies in differentiated markets. For instance, Collie (2003) shows that the optimal response to mergers in oligopoly markets would be to increase production subsidy post-merger. If production subsidies are raised post-merger this action will offset the anti-competitive effect of a merger. Similarly, Huck and Konard (2004) show that the optimal response of an otherwise laissez-faire country is to introduce subsidies after firms merge. Likewise Fikru and Lahiri (2013) consider a flexible policy regime in which governments adjust optimal policy after a cross-border merger takes place. Their study shows that post-merger the optimal adjustment is to increase production subsidy as long as local firms acquire a more efficient foreign firm. Hence, the general consensus in the merger literature is that laxer taxation (e.g., subsidies) is optimal in response to a merger due to the output distortion created (exacerbated) by the merger. None of these studies examine the role of product differentiation and pollution intensities in the characterization of optimal taxation in the presence of mergers. Our contribution to this literature is that we derive conditions under which stricter taxation is optimal, specifically in the presence of pollution intensities and product differentiation, even when market power increases following a merger.

Second, the literature on environmental policy in oligopoly markets shows that the type of market structure and number of firms affect optimal environmental policies. For example, Lahiri and Ono (2007) show that in Cournot oligopolies the effect of emission tax on welfare, production, and pollution depends on the specific market structure. On one hand studies like Ebert (1992), Katsoulacos and Xepapadeas (1996), Requate (2006) and Fujiwara (2009), just to name a few, suggest that an increase in market power limits production and pollution; hence, removing the need for stricter environmental regulations. In contrast, our result suggests that, even if market power increases following a merger, the optimal tax may be higher post-merger due to asymmetries in pollution intensities. We also find cases where there is no need to change the optimal emission tax post-merger. Hence, relaxing environmental regulation when market power increases should not always be viewed as a prescriptive solution in oligopoly markets with pollution externalities. On the other hand, studies like Simpson (1995) show that stricter taxation is optimal in Cournot markets where asymmetries in pollution intensity are present. The idea here is that a higher emission tax yields efficiency gains by discouraging inefficient firms in the market. Even though our analysis does not delve into efficiency aspects, it introduces cases where (in the presence of mergers) higher taxation is optimal even if asymmetries in efficiency are absent.

A third branch of the literature examines the role of product differentiation on optimal policy (e.g., Fujiwara, 2009; Poyago-Theotoky, 2003; McGinty and Vries, 2009) and reducing industry emissions (e.g., Lahiri and Symeonidis, 2007; Gautier, 2013, 2014, 2016). None of these works look at the role of product differentiation in the presence of mergers. We contribute to this literature by showing that the degree of product differentiation, in the presence of mergers, plays a crucial role in optimal taxation: markets characterized by very differentiated markets are associated with small differences in taxation pre- and post-merger, whereas in the case of homogeneous goods taxation post-merger could be stricter vis-à-vis pre-merger taxation.

Mergers have a profound effect that goes beyond changing the number of firms in a market (Huck et al., 2004). On the one hand, mergers may facilitate innovation some of which are in cleaner technologies, synergies in reducing pollution intensities and the creation of high quality greener products (Swart and Marrewijk, 2011; Bena and Li, 2014). On the other hand, merging firms may prioritize growth, efficiency improvements and value creation at the expense of environmental protection. In both cases it is important to study if, how and why optimal environmental policies change as a response to mergers.

Section 2 presents the model framework solving for equilibrium values before and after a two-firm merger takes place. Section 2.3 presents the welfare maximization problem and implications for the optimal choice of policy pre- and post-merger. Section 3 compares the pre-and post-merger optimal policies. In section 4.1 we focus on the role of pollution intensity by keeping fixed the level of product differentiation. In section 4.2 we focus on the role of product differentiation and number of firms by keeping fixed the pollution intensity. In section 5 we conclude by forwarding some questions for future research.

2 The Model

This section presents the main features of the model. Consider a Cournot oligopoly market where firms compete in a closed economy for the production of an imperfect substitute. The production of the good creates environmental externalities such as GHG emissions. Hence, each firm faces an emission tax and employs pollution abatement techniques. We consider a fixed number of n firms where each firm produces a differentiated product.

The demand function faced by each firm is adopted from Fujiwara (2009) and Cellini et al. (2004) and derived from preferences such that $P_i = \alpha - (\beta - \gamma)q_i - \gamma \sum_{i=1}^{n} q_i$, satisfying $\beta \geq \gamma \geq 0$, $\alpha > 0$ $\forall i$, where γ represents the degree of product differentiation in the industry. $\gamma = 0$ captures the extreme case where products are extremely differentiated. $\gamma = \beta$ represents the extreme case of completely homogeneous goods. If products are completely homogeneous we have the usual market demand $P_i = \alpha - \beta \sum q_i$. If products are completely differentiated, the demand function for product i would be $P_i = \alpha - \beta q_i$.

Each firm pays a per unit emission tax, t, for the level of pollution it fails to abate. Therefore, the government collects te_i from each firm as tax revenue where e is the emission level. The emission tax can be thought of a carbon tax of t dollars per ton of carbon dioxide emissions. We follow Requate (2006) for the structure of the cost function for each firm $i (i = 1, 2, \ldots, n)$. In particular, consider a cost function $C = C(q, e)$ where q and e denote, respectively, output and emissions for each firm. The function $C(\cdot)$ satisfies (subscripts denote partial derivatives) $C_q > 0$, $C_e < 0$, $C_{eq} < 0$, $C_{qq} > 0$, $C_{ee} > 0$, $C_{ee}C_{qq} - C_{qe}^2 > 0$. As in Lahiri and Symeonidis (2007) we define the pollution intensity as the ratio $-C_{eq}/C_{ee}$.[2]

The government and firms play a two-stage game where the government sets policy (i.e., emission tax) via social welfare maximization. Firms then take the policy as given and maximize profits by simultaneously choosing the level of output and emissions in a Cournot-Nash fashion. The assumption of simultaneous decision on output and emissions assumes away issues of the strategic choice of abatement; these have been analyzed elsewhere (e.g., Montero, 2002a, 2002b; Carlsson, 2000).

We assume interior solutions and symmetric equilibrium throughout the analysis (Qiu and Zhou, 2006). Asymmetry in marginal cost of production affects the optimal taxation in Cournot markets where mergers take place (Fikru and Lahiri, 2013). Thus, by assuming symmetry we exclude the role of differences in production efficiency in affecting the optimal tax response. This assumption has also been used in studies which examine other types of policy responses to mergers (Collie, 2003; Huck and Konard, 2004). We solve the model by backwards induction, first solving for the firm's problem and then solving for welfare maximization.

2.1 Pre-merger market

We characterize the equilibrium in the market before any mergers take place. Define profits for firms in the pre-merger market as follows

$$\pi_i = P_i q_i - C_i(q_i, e_i) - e_i t \quad i = 1, 2, \ldots, n \tag{1}$$

Each firm i maximizes π_i by choosing q_i and e_i in a Cournot-Nash fashion, which under symmetry ($q_1 = q_2 = ... = q$, and $e_1 = e_2 = ... = e$) gives

$$P - \beta q - C_q = 0 \tag{2}$$

$$-C_e - t = 0 \tag{3}$$

[2]This ratio arises from differentiation of $C_e(q, e)$; that is, $dC_e = C_{eq}dq + C_{ee}de = 0 \Rightarrow -C_{eq}/C_{ee}$.

where $P = \alpha - q(\beta + \gamma(n-1))$ and t denotes the tax faced by firms in the pre-merger market. The term βq captures the degree of output distortion in the pre-merger market. Equations (2) and (3) implicitly determine the equilibrium output and emissions in the pre-merger market.

Differentiation of (2) and (3) gives the effects of tax and product differentiation on output and emissions:

$$dq = \frac{(C_{eq}/C_{ee})dt}{\left(2\beta + \gamma(n-1) + (C_{qq}C_{ee} - C_{qe}^2)/C_{ee}\right)} - \frac{q(n-1)d\gamma}{\left(2\beta + \gamma(n-1) + (C_{qq}C_{ee} - C_{qe}^2)/C_{ee}\right)} \quad (4)$$

$$de = -\frac{C_{eq}}{C_{ee}}\left[\frac{(C_{eq}/C_{ee})}{\left(2\beta + \gamma(n-1) + (C_{qq}C_{ee} - C_{qe}^2)/C_{ee}\right)} + 1/C_{qe}\right]dt$$
$$+ \frac{C_{eq}}{C_{ee}}\left[\frac{(n-1)q}{\left(2\beta + \gamma(n-1) + (C_{qq}C_{ee} - C_{qe}^2)/C_{ee}\right)}\right]d\gamma \quad (5)$$

where $C_{eq} < 0$, $C_{ee} > 0$, $C_{qq}C_{ee} - C_{qe}^2 > 0$ and $-C_{eq}/C_{ee} > 0$ denotes pollution intensity. The above imply that output and emissions fall with the tax and rise with more differentiated products (decrease in γ). These results are consistent with the literature (Requate, 2006; Fujiwara, 2009; Gautier, 2015). For example, in a Cournot oligopoly market with fixed number of firms Lahiri and Ono (2007, p. 118) show that an increase in the emission tax always decreases firm output because it increases the marginal cost of production. Hence, an increase in the tax makes the oligopoly distortion relatively worse in the sense that it reduces production. They also show that an increase in the emission tax reduces emissions.

2.2 Post-merger market

Suppose that out of the n firms in the market, two firms, say firm 1 and firm 2 merge. As in Qiu and Zhou (2006) a merger can be considered as the combination of two firms where the newly formed merged entity maintains two separate product lines post-merger. Furthermore, when firms 1 and 2 merge, they make decisions to maximize their joint profits

(Qiu and Zhou, 2006). Profits for firm 1 and firm 2, respectively, are defined as follows:

$$\pi_1 = P_1 q_1 - C(q_1, e_1) - e_1 t_m \tag{6}$$

$$\pi_2 = P_2 q_2 - C(q_2, e_2) - e_2 t_m \tag{7}$$

where q_i and e_i denote output and emissions and P_i the inverse market demand function for $i = 1, 2$; t_m denotes the tax firms face in the post-merger market. Further, define profits for the other firms which do not merge ('outsiders' according to Salant et al. 1983) but are still competing against each other and the merged entity in the post-merger market:

$$\tilde{\pi}_i = \tilde{P}_i \tilde{q}_i - C_i(\tilde{q}_i, \tilde{e}_i) - \tilde{e}_i t_m \quad i = 3, 4, \ldots, n \tag{8}$$

Firms 1 and 2 maximize joint profits, $\pi_1 + \pi_2$, by choosing q_1, q_2, e_1, e_2 in a Cournot-Nash fashion which yields

$$P_1 - \beta q_1 - \gamma q_2 - C_{q_1} = 0 \tag{9}$$

$$-C_{e_1} - t_m = 0 \tag{10}$$

$$P_2 - \beta q_2 - \gamma q_1 - C_{q_2} = 0 \tag{11}$$

$$-C_{e_2} - t_m = 0 \tag{12}$$

where $P_1 = \alpha - \beta q_1 - \gamma q_2 - \gamma \tilde{q}(n-2)$ and $P_2 = \alpha - \beta q_2 - \gamma q_1 - \gamma \tilde{q}(n-2)$. In contrast to the pre-merger market, in the post-merger market the first-order conditions of firms 1 and 2 incorporate the degree of product differentiation by the colluding firms through the merger. This is captured by the term $\beta + \gamma$. This means that the degree of product differentiation accounts for the ability of merged firms to restrict output in order to raise profits to the extent permitted by the degree of product differentiation (Fikru and Gautier, 2016, p. 69). This plays an important role later in section 4.2. Specifically, product differentiation has a role in affecting output distortion which is one of the factors (the other factor is pollution intensity) that dictate the change in optimal policy post-merger.

Imposing symmetry yields two equations which characterize the equilibrium output, $q_1 = q_2$, and emissions, $e_1 = e_2$, for the two merged firms:

$$\alpha - 2q_1(\beta + \gamma) - \gamma\tilde{q}(n-2) - C_{q_1} = 0 \tag{13}$$

$$-C_{e_1} - t_m = 0 \tag{14}$$

The rest of the firms $i = 3, 4, \ldots, n$ (or outsiders) maximize $\tilde{\pi}$ by choosing $\tilde{q}$ and $\tilde{e}$ in a Cournot-Nash fashion which under symmetry yields

$$\alpha - 2\beta\tilde{q} - 2\gamma q_1 - \gamma(n-3)\tilde{q} - C_{\tilde{q}} = 0 \tag{15}$$

$$-C_{\tilde{e}} - t_m = 0 \tag{16}$$

where $\tilde{P} = \alpha - \beta\tilde{q} - 2\gamma q_1 - \gamma(n-3)\tilde{q}$. Equations (13) - (16) implicitly determine the equilibrium output and emissions, q_1, $\tilde{q}$, e_1, $\tilde{e}$.

The comparative statics analysis of the post-merger equilibrium is presented in the appendix. Consistent with the literature (e.g., Requate, 2006, pp. 140-142; Lahiri and Ono, 2007) the analysis suggests that output and emissions fall with a tax increase i.e., $\partial q_1/\partial t_m < 0$, $\partial\tilde{q}/\partial t_m < 0$, $\partial e_1/\partial t_m < 0$, $\partial\tilde{e}/\partial t_m < 0$.

2.3 Welfare and optimal tax

We characterize the optimal tax in the pre-and post-merger markets, respectively. To avoid the proliferation of cases we shall assume a positive optimal tax throughout. In the pre-merger market the government solves

$$\max_t W = CS(nq) + n\pi + net - \varphi(ne) \tag{17}$$

where $CS(\cdot)$ denotes consumer surplus and φ denotes damages from pollution satisfying $\varphi' > 0$, $\varphi'' > 0$. We assume strict concavity of the welfare function, $W(\cdot)$. Total differentiation gives

$$\begin{aligned} dW &= -nqdP + nd\pi + ntde + nedt - \varphi' nde \\ &= n(P - C_q)dq + n(t - \varphi')de \end{aligned}$$

where φ' denotes marginal damages from pollution. Differentiation with respect to the tax yields

$$\frac{\partial W}{\partial t} = n\beta q \frac{\partial q}{\partial t} + (t - \varphi')n\frac{\partial e}{\partial t} \tag{18}$$

where from first-order profit-maximization $P - C_q = -\beta q = q\partial P/\partial q$. The pre-merger optimal tax is thus characterized by setting (18) equal to zero.

In the post-merger market, the government solves

$$\max_{t_m} W_m = CS(q_1, q_2, (n-2)\tilde{q}) + \pi_1 + \pi_2 + (n-2)\tilde{\pi} + (e_1 + e_2)t_m + (n-2)\tilde{e}t_m$$
$$- \varphi(e_1 + e_2 + (n-2)\tilde{e}) \tag{19}$$

where $E_m = e_1 + e_2 + (n-2)\tilde{e}$ denotes total emission, $(n-2)\tilde{\pi}$ denotes profits of outsiders, $(n-2)\tilde{q}$ denotes output of outsiders. Additionally, we assume that the marginal damage function is identical across the pre- and post-merger scenarios; this is to facilitate the comparison of optimal policy across the two scenarios.

Assumption 2.1. *The marginal damage function, $\varphi'(\cdot)$, is identical across the pre- and post-merger scenarios.*

Differentiation gives (along with the first-order profit-maximization conditions and symmetry $q_1 = q_2$, $e_1 = e_2$)

$$\begin{aligned} dW_m &= -q_1 dP_1 - q_2 dP_2 - (n-2)\tilde{q}d\tilde{P} + d\pi_1 + d\pi_2 + (n-2)d\tilde{\pi} + E_m dt_m + (t_m - \varphi_m^{'})dE_m \\ &= 2(P_1 - C_{q_1})dq_1 + (n-2)(\tilde{P} - C_{\tilde{q}})d\tilde{q} + (t_m - \varphi')dE_m \end{aligned}$$

where $E_m = e_1 + e_2 + (n-2)\tilde{e} = 2e_1 + (n-2)\tilde{e}$, and $(P_1 - C_{q_1}) = (P_2 - C_{q_2}) = q_1(\beta + \gamma)$, $(\tilde{P} - C_{\tilde{q}}) = \beta\tilde{q}$. Hence,

$$\frac{\partial W_m}{\partial t_m} = 0 \Rightarrow t_m - \varphi' = \left[\frac{-2q_1(\beta+\gamma)\frac{\partial q_1}{\partial t_m} - \beta\tilde{q}(n-2)\frac{\partial \tilde{q}}{\partial t_m}}{\partial E_m/\partial t_m}\right] < 0 \tag{20}$$

where $\partial q_1/\partial t_m < 0$, $\partial \tilde{q}/\partial t_m < 0$, $\partial E_m/\partial t_m < 0$. The right-hand-side term in square brackets captures the role of the output distortion in the characterization of the post-merger tax, t_m.

For instance, a relatively large value (in absolute terms) of the term in square brackets implies that the output distortion is large and so the tax post-merger falls accordingly below marginal damages.

3 Comparing optimal policy pre- and post-merger

To address our research question of what the optimal policy response is to mergers among polluting firms we compare the optimal tax pre- and post-merger. To make such comparison we substitute (20) into (18) and examine the sign. If positive, then we may say that the post-merger tax, t_m, is less than the pre-merger tax, t. If negative, then the post-merger tax, t_m, is greater than the pre-merger tax, t. If zero, we may say that t_m is equal to t. We derive and discuss conditions under which the pre-merger tax may be different (smaller or larger) from the post-merger tax.

Substituting (20) into (18) gives:

$$\left.\frac{\partial W}{\partial t}\right|_{t_m} = n\beta q\frac{\partial q}{\partial t} - \left[\frac{2q_1(\beta+\gamma)\frac{\partial q_1}{\partial t_m} + \beta\tilde{q}(n-2)\frac{\partial \tilde{q}}{\partial t_m}}{\partial E_m/\partial t_m}\right] n\frac{\partial e}{\partial t} \tag{21}$$

where $\partial E_m/\partial t_m < 0$, $\partial q/\partial t < 0$, $\partial q_1/\partial t_m < 0$, $\partial \tilde{q}/\partial t_m < 0$, $\partial e/\partial t < 0$. The first term in (21), $n\beta q\partial q/\partial t$, captures the role of the output distortion in the characterization of the pre-merger tax, t. The role of pollution abatement via the tax is captured by the term $\partial E_m/\partial t_m$. The relationship between t and t_m and the sign of (21) depends on three things: the extent of output distortion, the extent of damages from pollution, and the presence of pollution abatement via the tax. We outline each of these three channels below.

First, if the output distortion in the post-merger equilibrium is large so that the term in square brackets is relatively large, then (21) is positive. With strict concavity of the welfare function this implies that $t_m < t$. Thus, the tax in the post-merger market is smaller than in the pre-merger market if output distortion post-merger is large. On the contrary, if the output distortion in the pre-merger equilibrium is large so that the term in square brackets is relatively small, then (21) is negative. This leads to $t_m > t$.

Second, by the same token if the damage from pollution post-merger is relatively small, then the tax post-merger is smaller than the tax pre-merger. However, a sufficiently high pollution damage in the post-merger market would result in $t_m > t$. This is because a higher tax is required to tackle higher pollution.

Third, we point out to the role of pollution abatement via the tax. In the presence of pollution abatement via the tax the role of the output distortion in the characterization of the optimal tax, t_m, becomes smaller (i.e., the term in square brackets in (21) is smaller); this is because with more abatement firms pay less in taxes per unit of output, thereby raising profits and output. As a result, the difference between the optimal tax and marginal damages becomes smaller. This effect renders the tax post-merger less likely to be smaller than the tax pre-merger via the output distortion channel.

To illustrate these effects we re-write equation (21) as follows

$$-\frac{\partial E_m}{\partial t_m}\left.\frac{\partial W}{\partial t}\right|_{t_m} = -n\beta q \frac{\partial q}{\partial t}\frac{\partial E_m}{\partial t_m} + n\frac{\partial e}{\partial t}\left[2q_1(\beta+\gamma)\frac{\partial q_1}{\partial t_m} + \beta\tilde{q}(n-2)\frac{\partial \tilde{q}}{\partial t_m}\right] \tag{22}$$

Based on this we find that $t_m < t$ *if and only if* the following inequality holds:

$$\frac{2q_1(\beta+\gamma)\partial q_1/\partial t_m + \beta\tilde{q}(n-2)\partial\tilde{q}/\partial t_m}{\partial E_m/\partial t_m} > \frac{\beta q \partial q/\partial t}{\partial e/\partial t} \tag{23}$$

The left-hand-side of equation (23) denotes the weight of the output distortion relative to damages from pollution in the post-merger market, and the right-hand-side captures the weight of the output distortion relative to damages from pollution in the pre-merger market. Thus, the tax post-merger is smaller than the tax pre-merger *if and only if* the output distortion, relative to damages from pollution, is sufficiently large in the post-merger market. If output distortion, relative to damages from pollution, is sufficiently small post-merger then $t_m > t$.

In contrast to the merger literature which argues that laxer taxation is optimal post-merger due to market power effects (Fikru and Lahiri, 2013; Collie, 2003, Huck and Konard, 2004), our analysis suggests that relaxing environmental policies is not always an optimal post-merger solution. This is because our model accounts for a potential change in pollution damages when the market structure changes due to the merger. In this sense, our model provides a more general case while previous studies indirectly assume that the change in market power (due to mergers in our case) is not accompanied by changes in pollution damage. In addition, our finding suggests that the adjustment in environmental policy crucially depends on information on output distortion as well as environmental performance of merger participants. This may require coordination and communication between environmental policy makers and other agencies such as anti-trust agencies.

Proposition 3.1. *The tax post-merger, t_m, is larger than the tax pre-merger, t, if and only if the output distortion, relatively to damages from pollution, is sufficiently small post-merger.*

4 The Case of an End-of-the-Pipe Cost Function

In order to further compare taxes pre- and post-merger we assume a cost function of the end-of-pipe-type as in Lahiri and Symeonidis (2007). That is, for each firm i ($i = 1, 2, \dots, n$) $C(q_i, e_i) = cq_i + (\delta_i q_i - e_i)^2/2$, where $\delta_i > 0$ is pollution intensity for each output variety. Similar to Salant et al. (1983) and Qiu and Zhou (2006, 2007) firms (pre- and post-merger) have identical constant marginal cost of production, $c \geq 0$; this is to eliminate any merger incentives associated with efficiency gains and synergy. In this way we can eliminate the need for policy adjustment as a result of loss or gain in efficiency post-merger (Fikru and Lahiri, 2013). Merged firms and outsiders in the post-merger equilibrium exhibit pollution intensity, δ_m. And pre-merger firms exhibit pollution intensity, δ.

Under this cost structure we obtain closed-form solutions for the pre- and post-merger equilibria using the first-order conditions from section 2 (see the appendix for a detailed derivation). We use the closed-form solutions to derive conditions to show that (i) for sufficiently small pollution intensity coefficient post-merger, δ_m, the tax post-merger is smaller than the tax pre-merger via the damage from pollution channel, and (ii) for large enough δ_m the tax post-merger is smaller because a large pollution intensity post-merger reduces output post-merger, thereby exacerbating the output distortion post-merger.[3]

To see these results we re-write equation (22) with $\beta = 1$, which implies $\gamma \in [0, 1]$:

$$\frac{-\phi}{n} \left.\frac{\partial W}{\partial t}\right|_{0\leq\gamma\leq 1, \delta\neq\delta_m, t_m, \beta=1} = -q\frac{\partial q}{\partial t}\left(2\delta_m\frac{\partial q_1}{\partial t_m} + (n-2)\delta_m\frac{\partial \tilde{q}}{\partial t_m} - n\right) + \left(2q_1(1+\gamma)\frac{\partial q_1}{\partial t_m} + (n-2)\tilde{q}\frac{\partial \tilde{q}}{\partial t}\right)\left(\delta\frac{\partial q}{\partial t} - 1\right) \tag{24}$$

where $\phi := \partial E_m/\partial t_m = 2\delta_m \partial q_1/\partial t_m + (n-2)\delta_m \partial \tilde{q}/\partial t_m - n < 0$, where the last term, n, denotes the pollution abatement via the tax post-merger, and $\partial e/\partial t = \delta\partial q/\partial t - 1 < 0$, where the last term also denotes abatement via the tax pre-merger; additionally, recall that under symmetry $q_1 = q_2$.

For sufficiently small level of pollution intensity post-merger, δ_m, the tax post-merger is smaller than the tax pre-merger: a relatively smaller tax post-merger can be set since the damage from pollution post-merger is relatively small. The following condition gives $t_m < t$ via the pollution damage channel: (24) is positive *if and only if*

$$\frac{\delta_m}{\delta} < \frac{\left(2q_1(1+\gamma)\frac{\partial q_1}{\partial t_m} + (n-2)\tilde{q}\frac{\partial \tilde{q}}{\partial t}\right)\left(\frac{\partial q}{\partial t} - 1/\delta\right)/\delta}{q\frac{\partial q}{\partial t}\left(2\frac{\partial q_1}{\partial t_m} + (n-2)\frac{\partial \tilde{q}}{\partial t_m} - n/\delta_m\right)} \tag{25}$$

Next, we derive a condition under which $t_m < t$ via the output distortion channel. Substitution of q_1, $\tilde{q}$, q, $\partial q_1/\partial t_m$, $\partial \tilde{q}/\partial t_m$, $\partial q/\partial t$ into (24) yields the following expression.

[3] Notice that for (i) the pollution intensities, δ_m and δ, are the terms associated with emissions, and for (ii) the pollution intensities are associated with the output distortion.

We assume without loss of generality that $c = 0$.

$$\frac{-\phi}{n}\left.\frac{\partial W}{\partial t}\right|_{0\leq\gamma\leq 1,\delta\neq\delta_m,t_m,\beta=1} = \frac{\delta(\alpha-\delta t_m)}{(2+\gamma(n-1))^2}\left(\frac{-\delta_m^2(2-\gamma)}{2+\gamma(n-1)-\gamma^2}-\frac{\delta_m^2(n-2)}{2+\gamma(n-1)-\gamma^2}-n\right)$$
$$+\left(\frac{-2(1+\gamma)\delta_m(\alpha-\delta_m t_m)}{(2+\gamma(n-1)-\gamma^2)^2}-\frac{(n-2)\delta_m(\alpha-\delta_m t_m)}{(2+\gamma(n-1)-\gamma^2)^2}\right)\left(-\frac{\delta^2}{2+\gamma(n-1)}-1\right) \tag{26}$$

whence $t_m < t$ *if and only if*

$$\frac{\delta_m}{\delta} > \frac{\frac{(\alpha-\delta t_m)}{(2+\gamma(n-1))^2}\left(\frac{\delta_m^2(2-\gamma)}{2+\gamma(n-1)-\gamma^2}+\frac{\delta_m^2(n-2)}{2+\gamma(n-1)-\gamma^2}+n\right)}{\left(\frac{-2(1+\gamma)(\alpha-\delta_m t_m)}{(2+\gamma(n-1)-\gamma^2)^2}-\frac{(n-2)(\alpha-\delta_m t_m)}{(2+\gamma(n-1)-\gamma^2)^2}\right)\left(\frac{-\delta^2}{2+\gamma(n-1)}-1\right)} \tag{27}$$

This condition says that because a sufficiently large pollution intensity post-merger reduces output post-merger, thereby exacerbating the output distortion, the tax post-merger is relatively smaller in order to address this output distortion.

Remark 4.1. *The conditions in (25) and (27) hold with the general cost function and $\beta \neq 1$.*

Proposition 4.2. *Let $\gamma \in [0, 1]$. Then, optimal tax post-merger, t_m, is smaller than the tax pre-merger, t, if (i) the pollution intensity coefficient post-merger, δ_m, is small so that damages from pollution are relatively small, and/or (ii) the pollution intensity coefficient post-merger is large so that the output distortion post-merger is relatively large.*

We extend the analysis in the next two sub-sections by examining the role of pollution intensity (for a given level of γ) and the role of product differentiation and number of firms when pollution intensities pre- and post-merger are identical (i.e., $\delta_m = \delta = \hat{\delta}$).

4.1 The role of pollution intensity

In this sub-section we examine the potential role of pollution intensity on the optimal emission tax. To do this, we fix the level of product differentiation at the extreme ends. That is, two cases of $\gamma = 0$ and $\gamma = 1$ where pollution intensity pre- and post-merger differ. Note that as product differentiation decreases, output distortion is exacerbated. That is, $\gamma = 1$ means that the merged entity has more power to restrict output and hence increase the output distortion. As before the analysis indicates that there are two key channels whereby taxes differ, namely, damages from pollution intensities and the extent of the output distortion.

In the case where products are completely differentiated (i.e., $\gamma = 0$) equation (26) can be re-written as

$$\frac{-\phi}{n}\frac{\partial W}{\partial t}\bigg|_{\gamma=0,\delta\neq\delta_m,t_m,\beta=1} = \frac{\delta(\alpha-\delta t_m)}{4}\left(-\frac{n\delta_m^2}{2}-n\right)+\frac{\delta_m n(\alpha-\delta_m t_m)}{4}\left(\frac{\delta^2}{2}+1\right) \tag{28}$$

It is noteworthy that (28) is equal to zero when pollution coefficients are equal, which is analogous to the analysis in section 4.2 when products are completely differentiated. The first (second) term in parenthesis captures, as before, the need to tackle damages from pollution post (pre)-merger. Additionally, the last terms in the expressions in parenthesis denote pollution abatement induced by the tax since the terms in parenthesis come from, respectively, $\partial E_m/\partial t_m$ and $\partial e/\partial t$. Moreover, in the first term, the expression not in parenthesis captures the need to address the output distortion pre-merger, whereas in the second term, the expression which is not in parenthesis, captures the need to address output distortion post-merger.

From (28) a condition analogous to (25) can be easily derived, which says that $t_m < t$ since pollution intensity is relatively smaller post-merger.[4] But importantly, if pollution abatement via the tax is sufficiently small this condition reduces to the following necessary and sufficient condition which ensures that the tax post-merger is smaller than the tax pre-merger: $\alpha(\delta - \delta_m) > 0$. This suggests that output, emissions and therefore taxes pre- and post-merger differ exclusively via pollution coefficients when products are completely differentiated.

Proposition 4.3. *Let $\delta \neq \delta_m$ and products be completely differentiated ($\gamma = 0$). Then, in the case where pollution abatement via the tax is sufficiently small, the tax post-merger is*

[4] An analogous condition to (27) can be derived from (28).

larger than the tax pre-merger if and only if pollution intensity post-merger is larger than pollution intensity pre-merger ($\delta < \delta_m$).

Next, we look at the second extreme case where products are homogeneous ($\gamma = 1$). The two key channels driving the results are identical to those in the preceding paragraphs and conditions analogous. Now, however, because goods are homogeneous the ability of the merged firm to restrict output increases and so the output distortion post-merger is exacerbated, thereby affecting how taxes compare post- and pre-merger. To see this in the case where $\gamma = 1$ equation (26) can be re-written as[5]

$$\frac{-\phi}{n}\left.\frac{\partial W}{\partial t}\right|_{\gamma=1,\delta\neq\delta_m,t_m,\beta=1} = \frac{\delta(\alpha-\delta t_m)}{(n+1)^2}\left(-\frac{(n-1)\delta_m^2}{n} - n\right) + \frac{\delta_m(n+2)(\alpha-\delta_m t_m)}{n^2}\left(\frac{\delta^2}{n+1}+1\right) \tag{29}$$

Comparison of (28) and (29) suggests that the term in the first parenthesis is smaller (in absolute value) in (29): because of the output restriction when $\gamma = 1$, the need to tackle pollution due to post-merger output diminishes. This implies that it is more likely for the post-merger tax to be smaller than the tax pre-merger through the damage from pollution channel. Additionally, the second term (not in parenthesis) in (29) is positive and represents the effect associated with the output distortion when goods are homogeneous: because of the ability to restrict output post-merger the output distortion is exacerbated prompting a lower tax post-merger.

Remark 4.4. *Let $\delta \neq \delta_m$ and products be homogeneous ($\gamma = 1$). Then, the tax post-merger is more likely to be smaller than the tax pre-merger due to the output restriction by the merged entity when goods are homogeneous.*

The above remark concurs with the implication of previous studies (e.g., Collie, 2003). However we consider (29) and argue that even in the case where goods are homogeneous, and

[5] We use the fact that at $\gamma = 1$: $2q_1 = \tilde{q}$ and $2\partial q_1/\partial t_m = \partial\tilde{q}/\partial t_m$.

therefore the tax post-merger is likely to be smaller than the tax pre-merger, the discrepancy in taxation becomes small for sufficiently large pollution intensity post-merger. In particular, consider (29) as a function of δ_m and suppose it is positive i.e., suppose $t_m < t$ because post-merger the output distortion vis-à-vis damages from pollution post-merger is relatively large. Specifically, from (29) we obtain[6]

$$\frac{\delta_m(n+2)(\alpha-\delta_m t_m)/n}{\delta_m^2(n-1)+n^2} > \frac{\delta(\alpha-\delta t_m)/(n+2)}{(\delta^2+n+1)} \tag{30}$$

where the numerator of the first and second term captures, respectively, the output distortion in the post- and pre- merger market. The denominator captures the damages from pollution in each market, respectively. If the pollution intensity post-merger is sufficiently large (i.e., $\delta_m \rightarrow \alpha/t_m$), then the left-hand-side of (30) becomes very small, which implies that the condition (inequality) in (30) does not hold. This means that the tax post-merger is no longer smaller than the tax pre-merger, and the discrepancy between the tax post- and pre-merger becomes small for large pollution intensity post-merger. This is because as the post-merger pollution intensity becomes large, post-merger damages from pollution increase thus resulting in a larger tax post-merger.[7]

Proposition 4.5. *Let $\delta \neq \delta_m$ and products be homogeneous ($\gamma = 1$). Then, for sufficiently large pollution intensity post-merger the tax post-merger is not smaller than the tax pre-merger even in the case where the output restriction arising of the merged firm is large.*

Our analysis has important policy implications for pollution-intensive industries which rely on frequent merger deals for growth. On one hand, policy makers should adjust policy

[6] This expression is analogous to (23).

[7] It is noteworthy that in (30) the tax t_m is a function of δ_m and thus t_m may rise/fall as δ_m rises. There are two possibilities. First, the tax may rise as δ_m rises. In this case the increase in the tax post-merger compensates the increase in δ_m: the numerator in the left-hand-side of (30) becomes smaller via the tax and also via the pollution intensity (for given tax). The left-hand-side term of (30) becomes smaller faster than the right-hand-side because of three factors: a larger denominator and a smaller numerator both through a reduction in δ_m and t_m. The right-hand-side term becomes smaller just via a reduction in the tax. Second, the tax post-merger may fall as δ_m rises thus having an ambiguous effect on the numerator of the left-hand-side term of (30). We are interested in the first case (i.e., where t_m rises with δ_m) since this case yields a clear-cut result which illustrates the factors leading to a larger tax post-merger even in the presence of restricted output due to the merger. The case where t_m rises (falls) with an increase in δ_m can be interpreted as a situation where the government puts more (less) weight on addressing higher pollution.

to be less strict if such industries show commitments towards improving their environmental performance post-merger.[8] On the other hand, if merger participants are not taking explicit steps to integrating cleaner production in their merger deals, then the recent global trend of tightening up environmental regulation would be consistent with welfare maximization goals.

4.2 The role of product differentiation and competition

In this sub-section we examine the potential role of product differentiation on the optimal tax adjustment. To do this we rule out the role of pollution intensity by assuming identical pollution intensity pre- and post-merger, $\delta = \delta_m = \hat{\delta}$.

We obtain the following expression from equation (26) under the demand and cost structures aforementioned, identical pollution intensity coefficients and, as before, without any loss of generality $c = 0$ and $\beta = 1$, where the latter implies $\gamma \in [0, 1]$. In particular, equation (26) can be re-written as follows

$$\begin{aligned} \left.\frac{\partial W}{\partial t}\right|_{0\leq\gamma\leq 1,\hat{\delta},t_m,\beta=1} &= \mu \Big[\hat{\delta}^2\gamma^2 \left(2-\gamma+\hat{\delta}(n-2)\right) + (1/2)\hat{\delta}^3\gamma(1-\gamma)(n-2)\left(2+\gamma(n-1)\right) \\ &+(1/2)\left(2+\gamma(n-1)\right)^2\left((1+\gamma)(2-\gamma)^2+2(n-2)\right) \\ &-n\left(2+\gamma(n-1)-\gamma^2\right)^2\Big] \end{aligned} \tag{31}$$

where $\mu = \hat{\delta}(\alpha-\hat{\delta}t_m)/(\hat{\delta}^2(n-\gamma)+n(2+\gamma(n-1)-\gamma^2))(2+\gamma(n-1)-\gamma^2)(2+\gamma(n-1))^2 > 0$, and to satisfy non-negative output $\alpha-\hat{\delta}t_m > 0$. We derive a set of results under the following definition based on equation (31).

Definition 4.6. *For all* $\gamma[0,1]$, $n > 3$, $f(\gamma) := \left.\frac{\partial W}{\partial t}\right|_{t_m,\beta=1,\hat{\delta}}$

[8] The role of commitment in policy making is important. For instance, Dixit (1997) emphasizes the importance of commitment in government policy making. Likewise, Aidt (1998) presents factors that cause governments to adopt taxes that considerably differ from the Pigovian rule. These aspects are key, but in this paper we assume governments will adopt optimal policies and there are no commitment issues on the side of the government.

Definition 4.6 says that $f(\cdot) \geq 0$ *if and only if* $t_m \leq t$

Proposition 4.7. *Let $\delta = \delta_m = \hat{\delta}$. Then, pre- and post-merger taxation is identical if products are completely differentiated.*

Proposition 4.7 can be stated formally using definition 4.6: (i) $f(0) = 0$; (ii) $f(\gamma) > 0 \; \forall \; \gamma \in (0, 1]$. Several remarks about these results are in order. First, (i) says that when products are completely differentiated (i.e., $\gamma = 0$) the tax is identical pre- and post-merger. The reason is that in the case where products are completely differentiated any difference between the level of output pre-and post-merger becomes small and therefore the level of emissions pre- and post-merger is similar since pollution intensities are assumed to be identical (i.e., $\delta_m = \delta = \hat{\delta}$). As a result, the tax is equal pre-and post-merger.

Second, (ii) implies that the tax post-merger is smaller than the tax pre-merger for any degree of product differentiation. But without further assumptions about parameter values and tax response (i.e., the sign of $dt_m/d\gamma$) we can not draw additional conclusions from the function $f(\gamma)$. The relationship between the degree of product differentiation and the difference between the tax pre- and post-merger is non-linear, however. For instance, for large values of n (and given pollution intensity coefficient, $\hat{\delta}$) the difference between the pre- and post-merger tax falls; this is because with a larger number of firms the output distortion becomes small and so the optimal tax pre- and post-merger is equal to marginal damages. To illustrate this point Figures 1-3 plot equation (31) for several values of n (for given $\hat{\delta} = 1$ and assuming $\alpha - \hat{\delta} t_m = 1$ for simplicity). The figures illustrate the role of competition in the need to adjust optimal policy post-merger. Specifically, the need to revise optimal environmental policy declines as the number of firms increases.

5 Conclusion

According to PwC (2013) a majority of corporate managers who anticipate to undertake merger and acquisition deals are from pollution-intensive industries such as chemical and metal manufacturing. Therefore, theoretical merger models should explicitly include pollution parameters and policies aimed at reducing pollution. In this paper, we examine the effect of mergers on optimal environmental taxation in a Cournot oligopoly market with product differentiation. Our chief result is that the adjustment in the emission tax crucially depends on the relative post-merger output distortion and pollution intensity (see Table 1 in the appendix for a summary of results). We show that taxation in the post-merger market may be stricter than taxation in the pre-merger market as long as damages from pollution are large. This result illustrates the important role of pollution intensity in the analysis of environmental policy in markets where frequent mergers take place. Moreover, we show that markets characterized by very differentiated products may not require a change in optimal policy (i.e., revision of the emission tax is not needed post-merger) thus suggesting that taxation in the presence of mergers is not necessarily laxer post-merger. We also explore the role of number of firms and show that no revision in taxation is needed when there are many firms.

The overarching objective of the present paper is to compare tax policy pre- and post-merger. The analysis, however, does not touch on a number of important research questions. For example, how do emissions, abatement, output, profits and welfare compare pre- and post-merger? In this regard we make a few remarks. First, the literature has delved into the comparison of output, profits and abatement pre- and post-merger. In particular, Fikru and Gautier (2016) derive conditions under which mergers are profitable and explore the role of pollution intensities and product differentiation on profitability. Thus, our chief contribution to the literature is on the comparison on taxes pre- and post-merger. Second, a potential line of future research would be to compare welfare pre- and post-merger. Even though this line of inquiry would require a more in-depth analysis, here we present an example to illustrate the various effects at play (Fikru and Gautier, 2016). Consider the case where the pollution intensity in the post-merger equilibrium is sufficiently small. In this case mergers are likely to be profitable and experience higher levels of output because in this case merged firms pay less in taxes (i.e., merged firms are less pollution-intensive). As a result, consumer surplus effects in the post-merger market are likely to be relatively large vis-à-vis the pre-merger market. Moreover, with a sufficiently small pollution intensity post-merger, damages from pollution in the post-merger market are likely to be small thereby raising welfare post-merger. Therefore, with sufficiently small pollution intensity welfare in the post-merger market is likely to be larger vis-à-vis the pre-merger market via higher profitability and consumer surplus effects, but also lower damages from pollution. Now, if differences across pre- and post-merger pollution intensities are not clear-cut, then welfare effects across the pre- and port-merger equilibria may be ambiguous, thereby suggesting a potential future line of research. The specific cases where output/profitability rise/fall with respect to the degree of product differentiation, the abatement induced by the tax and pollution intensities yield a myriad of cases, each of which have an impact on welfare. Therefore, a deeper analysis along these lines is warranted.

An important aspect in merger decisions and environmental policy is the presence of R&D e.g., environmental R&D. Matsushima et al. (2013) explores, among others, the role of R&D in the absence of environmental externalities, and Montero (2002a, 2002b), just to name a few, explore aspects of environmental R&D in the absence of mergers. Thus, we believe that an important future line of research consists of exploring the role of R&D on mergers, emissions, abatement and welfare pre- and post-merger. To illustrate, if R&D reduces marginal production and abatement costs, then emissions fall on the one hand via lower marginal abatement costs, but on the other production and thus emissions rise via the reduction in marginal production costs. As a result, the net effect on emissions is ambiguous. But if the pollution intensity coefficient is sufficiently small in the post-merger market (a small pollution intensity post-merger is one case we examine in section 3), then the increase in output (and thus emissions), which takes place via lower marginal cost, is small and, as a result, cost-reducing R&D results in lower emissions, higher output, abatement and profits. Welfare in the post-merger market will therefore compare favorably with the welfare in the pre-merger market. Given the potential number of cases and role of the degree of product differentiation, a more in-depth analysis on welfare and profitability would be needed to derive clear-cut conditions and results.

There are other dimensions in which the current model can be extended in future studies. One possible direction is relaxing some of the assumptions. For example, the adjustment in optimal policy may be different if the marginal damage function is allowed to differ in the pre- and post-merger markets. Relaxing this assumption will bring an additional channel whereby taxes differ pre- and post merger. Additionally, the policy adjustment may also depend on the size of the merger. That is, if more than two firms engage in the merger, the output distortion may be intensified and the post-merger tax could always be less than the pre-merger tax. Given the recent context of global environmental agreements, the analysis can be extended to incorporate the analysis of transboundary pollution, and how governments should design environmental policies after domestic and/or international mergers take place. Finally, the question of whether firms will still engage in a merger deal if they anticipate a less favorable change in policy can be addressed by extending the model given in this paper.

References

[1] Aidt, T.S. (1998).“ Political internalization of economic externalities and environmental policy” *Journal of Public Economics* 69:116.

[2] Bena, J., Li, K. (2014). Corporate Innovations and Mergers and Acquisitions. *Journal of Finance*, 69(5), 1923-1960.

[3] Blonigen, B.A and Pierce, J.R. (2015). The effects of mergers and acquisitions on market power and efficiency. Retrieved from http://pages.uoregon.edu/bruceb/blonigen_pierce_aug2015.pdf

[4] Carlsson, F. (2000). " Environmental taxation and strategic commitment in duopoly models" *Environmental & Resource Economics* 15(3): 243-256.

[5] Cellini, R., L. Lambertini and G.I.P. Ottaviano (2004). "Welfare in a differentiated oligopoly with free entry: a cautionary note" *Research in Economics* 58:125-133.

[6] Collie, D.R. (2003). "Mergers and trade policy under Oligopoly" *Review of International Economics* 11(1): 55-71.

[7] Damassa, T., Bianco, N., Fransen, T., Hatch, J. (2012). GHG mitigation in the United States: An overview of the current policy landscape. World Resources Institute Working Paper.

[8] Dixit, A., Grossman, G.M and Helpman, E. (1997). "Common Agency and Coordination: General Theory and Application to Government Policy Making" *Journal of Political Economy* 105(4): 752-769

[9] Ebert, U. (1992). "Pigouvian tax and market structure: The case of oligopoly and different abatement technologies" *FinanzArchiv/Public Finance Analysis* 49 (2): 154-166.

[10] Factset USA (2016). Flashwire US Monthly. US M&A News and Trends.

[11] Fikru, M.G and S. Lahiri (2013). "Cross-border mergers with flexible policy: The role of efficiency and market size" *Journal of the Japanese and International Economics* 34: 58-70.

[12] Fikru, M.G. and Gautier, L. (2016). "Mergers in Cournot markets with environmental externality and product differentiation" *Resource and Energy Economics* 45: 65-79

[13] Fujiwara, K. (2009). "Environmental policies in a differentiated oligopoly revisited" *Resource and Energy Economics* 31: 239-247.

[14] FW December 2012. Energy and utilities sector. *Financier Worldwide Magazine*

[15] Gautier, L. (2013). “Multilateral policy reform of emission taxes and abatement subsidies in a two-country model with oligopolistic interdependence” *Environmental Economics and Policy Studies* 15(1): 59-71.

[16] Gautier, L. (2014). “Policy reform of emission taxes and environmental research and development incentives in an international Cournot model with product differentiation” *Environment and Development Economics* 19(4): 440-465.

[17] Gautier, L. (2015). “Horizontal product differentiation and policy adjustment in the presence of abatement subsidies and emission taxes” *Journal of Environmental Economics and Policy* 4(1):64-81.

[18] Gautier, L. (2016). “Emission taxes and product differentiation in the presence of foreign firms” *Journal of Public Economic Theory* doi: 10.1111/jpet.12204.

[19] Hettige, H., Martin, P., Singh, M., and D. Wheeler (1995). “The Industrial Pollution Projection System” *Policy Research Working Paper* The World Bank.

[20] Huck, S and Konard (2004). “Merger profitability and trade policy” *Scandinavian Journal of Economics* 106(1): 107-122.

[21] Huck, S., Konard, K.A. and Muller W. (2004). “Profitable horizontal mergers without cost advantages: the role of internal organization, information and market structure” *Economia* 71(284), 575-587

[22] Katsoulacos, Y., Xepapadeas, A. (1996). Environmental Taxes and Market Structure. In: C. Carraro, Y. Katsoulacos, A. Xepapadeas (Eds), *Environmental Policy and Market Structure* (p. 3-22). The Netherlands; Dordrecht

[23] Lahiri, S. and G. Symeonidis (2007). “Piecemeal multilateral environmental policy reforms under asymmetric oligopoly” *Journal of Public Economic Theory* 9(5): 885-899.

[24] Lahiri, S, and Ono, Y. (2007). "Relative emission standard versus tax under Oligopoly: The role of free entry." *Journal of Economics* 91(2):107-128.

[25] Matsushima, N., Sato, T. and Yamamoto, K.(2013). "Horizontal mergers, firm heterogeneity, and R&D investments." *The BE Journal of Economic Analysis & Policy* 13.2: 959-990.

[26] McGinty, M. and F.P. de Vries (2009). "Technology diffusion, product differentiation and environmental subsidies" *B.E. Journal of Economic Analysis and Policy: Topics in Economic Analysis and Policy* **9**(1): 1-25.

[27] Montero, P. (2002a). "Permits, standards, and technology innovation" *Journal of Environmental Economics and Management* 44(1): 23-44.

[28] Montero, P. (2002b). "Market structure and environmental innovation" *Journal of Applied Economics* 5 (2): 293-325.

[29] Poyago-Theotoky, J. and K. Teerasuwannajak (2002). "The timing of environmental policy: A note on the role of product differentiation" *Journal of Regulatory Economics* 21: 305-316.

[30] PwC (2013). US CEO Survey. Creating values on uncertain times. Retrieved from http://www.pwc.com/gx/en/index.jhtml?ld=no

[31] Qiu, L.D., W. Zhou (2006). "International Mergers: Incentives and Welfare" *Journal of International Economics* 68(1): 38-58.

[32] Qiu, L.D., W. Zhou (2007). "Merger Waves: A Model of Endogenous Mergers" *RAND Journal of Economics* 38: 214-226.

[33] Requate, T. (2006). "Environmental policy under imperfect competition" in T. Tietenberg, & H. Folmer (Eds.) *The international yearbook of environmental and resource economics 2006/2007* (pp. 120-207). UK: Edward Elgar Publishing Limited.

[34] Salant, S. W., Switzer, S., R. Reynolds (1983). "Losses from Horizontal Merger: The Effect of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium" *The Quarterly Journal of Economics* 98: 185-199.

[35] Simpson, R.D. (1995). "Optimal Pollution Taxation in a Cournot Duopoly" *Environmental and Resource Economics* 6: 359-369.

[36] Swart, J., Marrewijk, C. (2011). The Pollution Effects of Mergers and Acquisitions: Asymmetry, Disaggregation, and Multilateralism. Tinbergen Institute

[37] Wooders, P. (2012). Energy-Intensive Industries: Decision making for a low-carbon future. The case of steel. International Institute for Sustainable Development.

Appendix

We examine the comparative static effects of the tax, t_m, in the post-merger equilibrium. Differentiation of (13)-(16) yields the following system

$$\begin{bmatrix} -2(\beta+\gamma) - C_{q_1q_1} & -\gamma(n-2) & -C_{q_1e_1} & 0 \\ -C_{e_1q_1} & 0 & -C_{e_1e_1} & 0 \\ -2\gamma & -2\beta-\gamma(n-3)-C_{\tilde{q}\tilde{q}} & 0 & -C_{\tilde{q}\tilde{e}} \\ 0 & -C_{\tilde{e}\tilde{q}} & 0 & -C_{\tilde{e}\tilde{e}} \end{bmatrix} \begin{bmatrix} dq_1 \\ d\tilde{q} \\ de_1 \\ d\tilde{e} \end{bmatrix} = \begin{bmatrix} 0 \\ dt_m \\ 0 \\ dt_m \end{bmatrix}$$

where the determinant of the coefficient matrix $\eta < 0$:

$$\eta = -C_{\tilde{e}\tilde{e}}C_{e_1e_1}\left[\left(2\beta+\gamma(n-3)+\frac{C_{\tilde{q}\tilde{q}}C_{\tilde{e}\tilde{e}}-C^2_{\tilde{e}\tilde{q}}}{C_{\tilde{e}\tilde{e}}}\right)\left(2(\beta+\gamma)+\frac{C_{q_1q_1}C_{e_1e_1}-C^2_{e_1q_1}}{C_{e_1e_1}}\right)-2\gamma^2(n-2)\right]$$

We follow Lahiri and Symeonidis (2007) in the definition of pollution intensity, $-C_{qe}/C_{ee} > 0$, where subscripts denote partial derivatives. When deriving the comparative statics analysis we assume *identical pollution intensity within firms in the post-merger market*; this is to facilitate the comparison with the pre-merger market. That is, $-C_{q_1e_1}/C_{e_1e_1} = -C_{\tilde{q}\tilde{e}}/C_{\tilde{e}\tilde{e}} > 0$.

Using the above system the effect of the tax post-merger on output, q_1 and $\tilde{q}$ is given by

$$\frac{\eta}{C_{e_1e_1}C_{\tilde{e}\tilde{e}}}dq_1 = \frac{-C_{e_1q_1}}{C_{e_1e_1}}\left[2\beta-\gamma+\frac{(C_{\tilde{e}\tilde{e}}C_{\tilde{q}\tilde{q}}-C^2_{\tilde{e}\tilde{q}})}{C_{\tilde{e}\tilde{e}}}\right]dt_m \tag{A.1}$$

$$\frac{\eta}{C_{e_1e_1}C_{\tilde{e}\tilde{e}}}d\tilde{q} = \frac{-C_{\tilde{e}\tilde{q}}}{C_{\tilde{e}\tilde{e}}}\left[2\beta+\frac{(C_{e_1e_1}C_{q_1q_1}-C^2_{e_1q_1})}{C_{e_1e_1}}\right]dt_m \tag{A.2}$$

where $2\beta-\gamma > 0$, and $C_{qq}C_{ee}-C^2_{eq} > 0$, $C_{ee} > 0$ by the properties of the cost function. Hence, output falls with the tax, i.e., $\eta < 0$ and $dq_1 > 0$, $d\tilde{q} > 0$.

The effects of the tax post-merger on emissions are given by:

$$\eta de_1 = -\frac{C_{e_1q_1}}{C_{e_1e_1}}\left[-C_{e_1e_1}C_{\tilde{e}\tilde{e}}\frac{C_{e_1q_1}}{C_{e_1e_1}}\left(2\beta-\gamma+\frac{(C_{\tilde{e}\tilde{e}}C_{\tilde{q}\tilde{q}}-C^2_{\tilde{e}\tilde{q}})}{C_{\tilde{e}\tilde{e}}}\right)+\eta/C_{e_1q_1}\right]dt_m \tag{A.3}$$

$$\eta d\tilde{e} = -\frac{C_{\tilde{e}\tilde{q}}}{C_{\tilde{e}\tilde{e}}}\left[-C_{e_1e_1}C_{\tilde{e}\tilde{e}}\frac{C_{\tilde{e}\tilde{q}}}{C_{\tilde{e}\tilde{e}}}\left(2\beta+\frac{(C_{e_1e_1}C_{q_1q_1}-C^2_{e_1q_1})}{C_{e_1e_1}}\right)+\eta/C_{\tilde{e}\tilde{q}}\right]dt_m \tag{A.4}$$

The expressions in (A.1)- (A.4) reduce to the following in the special case of the end-of-pipe-type cost function $C(q,e) = cq + (\delta q - e)^2/2$, where $C_{qq}C_{ee} - C^2_{eq} = 0$, $C_{ee} = 1$, $-C_{q_1e_1}/C_{e_1e_1} = -C_{\tilde{q}\tilde{e}}/C_{\tilde{e}\tilde{e}} = \delta$, where δ is a constant pollution intensity of firms:

Figure 1: The function $f(\gamma)$ where $\hat{\delta} = 1$, $5 \geq n \leq 10$

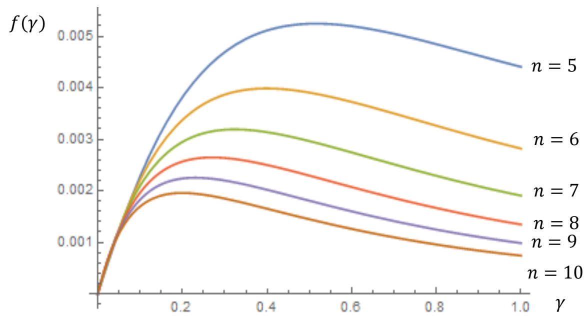

Figure 2: The function $f(\gamma)$ where $\hat{\delta} = 1$,$n = 20$, $n = 30$, $n = 40$, $n = 50$.

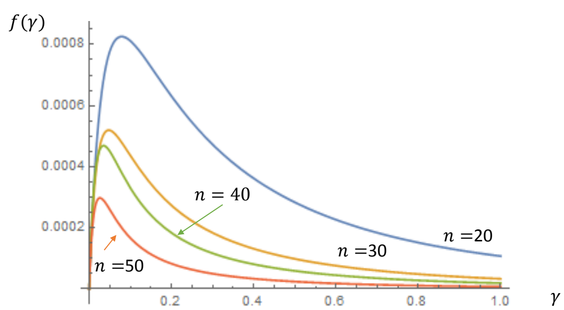

Figure 3: The function $f(\gamma)$ where $\hat{\delta} = 1$, $n = 100$, $n = 150$, $n = 200$.

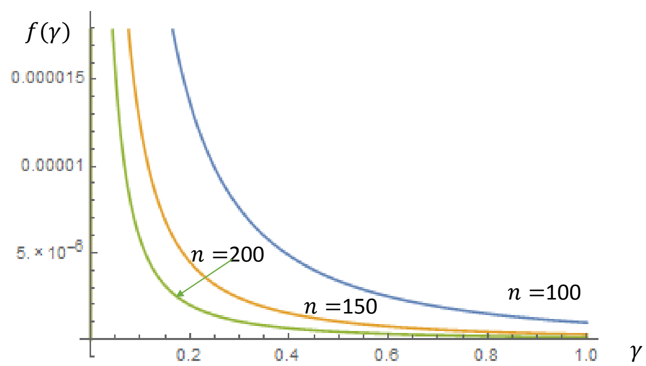

Table 1: Comparing optimal tax pre- and post-merger with end-of-the-pipe cost function.

Product differentiation	Pollution intensities	Operating channel	Taxes	Proposition
$0 \leq \gamma \leq 1$	$\frac{\delta_m}{\delta}$ small	Lower pollution damage post-merger	$t_m < t$	4.2
$0 \leq \gamma \leq 1$	$\frac{\delta_m}{\delta}$ large	Higher output distortion post-merger	$t_m < t$	4.2
$\gamma = 0$	$\delta_m \neq \delta$	Pollution abatement via tax is small	$t_m > t$ if $\delta_m > \delta$	4.3
$\gamma = 1$	$\delta_m \neq \delta$	Output distortion exacerbated post-merger	$t_m > t$ if δ_m is relatively very large	4.5
$\gamma = 0$	$\delta_m = \delta$	None	$t_m = t$	4.7